UCRL-JC-132026
PREPRINT

Testing and Diagnostic Capabilities at LLNL

Dennis Baum

This paper was prepared for submittal to the
49th Meeting of the Aeroballistic Range Association
Scheveningen, The Netherlands
October 5-9, 1998

September 24, 1998

Lawrence Livermore National Laboratory

DISCLAIMER

Testing and Diagnostic Capabilities at LLNL*

Dennis W. Baum

The importance and necessity of maintaining a strong test capability at LLNL has remained constant throughout the 46 year history of the Laboratory, even while the role of testing has undergone significant change. In the early years, testing was essential as the primary means of exploring and evaluating new technology areas and new design concepts. As hydrocodes were developed and began to be integrated into the design process, testing was required to validate the accuracy and correctness of the hydrocode calcalculations. More recently, however, with the advent of the Comprehensive Test Ban Treaty and the complete reliance on hydrocodes and other calculational tools for predicting behavior, ageing effects, and performance of weapons, the role of testing has not diminished. Rather, the ability to benchmark hydrocodes and material models against well posed and highly diagnosed scientific experiments has become an essential component of hydrocode validation.

In this role, experiments must be well-defined in terms of their configuration and descriptions of the materials utilized, and diagnosed with high resolution diagnostics to measure sensitive parameters that can be directly compared against hydrocode output. Also, the equations of state (EOS) and constitutive models for the materials must be accurately known over the entire range of parameters the material experiences. The material characterization process requires accurate and highly resolved experiments from which essential material behavior parameters can be extracted.

In some cases, new diagnostics must be developed to measure appropriate significant calculable parameters. An example of this is the current interest at LLNL and other laboratories to obtain an accurate measure of the temperature of a shocked and highly deformed metal. While knowledge of the temperature history experienced by a metal part during weapon operation is not of obvious value in understanding the performance of a weapon, the ability to predict material temperature correctly is highly dependent on the accuracy of the constitutive model used to describe the shocked and deformed material and therefore a sensitive indicator of the correctness of the model.

Testing activities today at LLNL occur at three different locations: Livermore, Site 300, and the Nevada Test Site. At the Livermore location, there are three gas guns, two of which are used primarily for materials studies and scientific experiments on materials. The third gun is located in the High Explosive Applications Facility (HEAF) and fires into a chamber rated for 10 kg of explosive containment. The HEAF gun is used primarily for impact studies on explosives. Also within HEAF are five other containment chambers for explosive testing. Each is instrumented to varying degrees to supply the necessary information of explosive behavior. These include high speed optics, Fabry Perot velocimetry and radiography. The descriptions of the three gas guns and a summary of the HEAF facility are presented in the accompanying figures.

Site 300 is the primary location for explosive testing, with currently three active firing bunkers B801, B850, and B851. The firing is currently done in the open air with an equivalent explosive weight limit of 1000 lbs. Local weather and atmospheric conditions are sampled twice each day and from that data, an allowable firing weight for that day is established. The largest and most complete diagnostics capabilities are situated in Bunker 801, which features the FXR, a high energy, high dose, penetrating x-ray machine. FXR is currently being upgraded to add a second pulse capability, and will soon undergo a major modification with the addition of the Contained Firing Facility (CFF). This modification will completely enclose the firing area and is rated for a capacity of 60 kg of high explosive. A separate talk at this meeting by Larry Simmons discusses this facility.

A specific design point for each of the firing bunkers is the incorporation and integration of all diagnostic capabilities to be used simultaneously on a test, thereby maximizing the amount of information obtained from each test. A typical explosive test at S-300 will incorporate radiography (high energy, standard 450kV, or both), several Cordin framing cameras, the 8 frame image converter camera, streak cameras, Fabry-Perot velocimetry, and assorted foil and pin switches.

Several additional facilities are located at S-300, including the SHARP gun, which was discussed at the 46th ARA meeting.

An additional LLNL explosive firing capability was added to the Nevada Test Site over the last five years. A bunker complex, constructed during the period of atmospheric testing, was converted into a firing facility having a full suite of diagnostics, similar to S-300, and having an explosive weight limit of 70,000 lb. The facility is called Big Explosive Experiment Facility (BEEF). At this location, large shots can be fired without weather considerations and sophisticated diagnostics are available. To date, the largest shot fired at BEEF was 5 Tons as part of the qualification of the bunker.

The accompanying charts present much additional information on each of these locations and the diagnostic capabilites.

---

* Work performed under the auspices of the Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

DOE Lawrence Livermore National Laboratory

- Employees
  - Staff: 7,000
  - Other: 500
- Capital Plant: $4B
- Annual Operating and Capital funds:
  - ~$1B/yr

Managed by the University of California since 1952

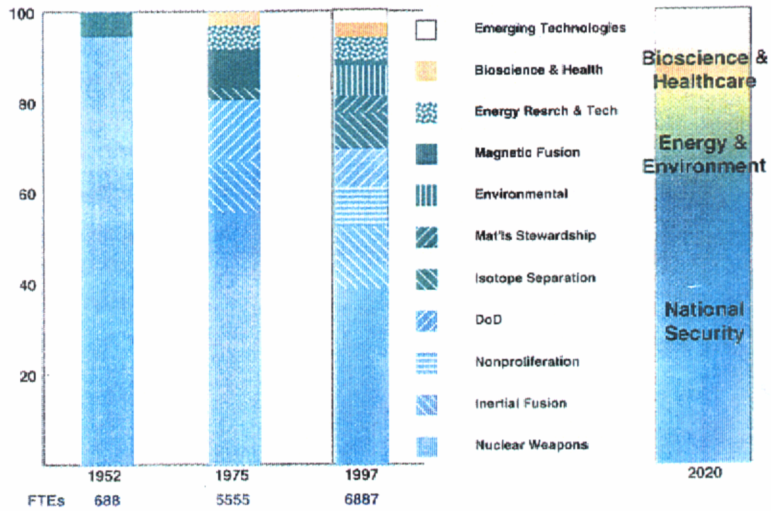
MOU-98-002. 2

LLNL Mission Statement

- Short form
  - Ensure national security and apply science and technology to the important problems of our time
- Full form
  - Lawrence Livermore National Laboratory is a premier applied-science national security laboratory
  - Our primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable and to prevent the spread and use of nuclear weapons worldwide
  - This mission enables our programs in advanced defense technologies, energy, environment, biosciences, and basic science to apply Livermore's unique capabilities, and to enhance the competencies needed for our national security mission
  - The Laboratory serves as a resource to U.S. government and a partner with industry and academia

MOU-98-002. 3

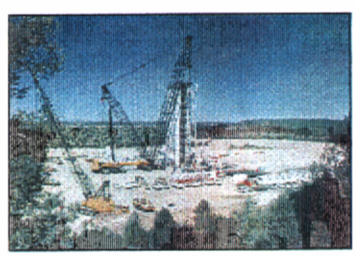
The Laboratory's programmatic evolution



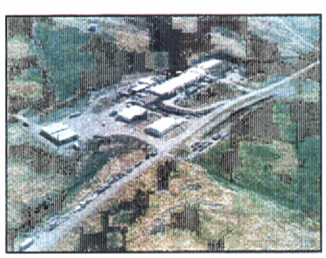
MOU-98-002. 4

Our people work at three separate locations

Livermore



Nevada Test Site



Site 300

MOU-98-002. 5

Historical and current technical approach at LLNL

- Develop and implement computational tools (hydrocodes and material models) to predict the results of complex dynamic experiments
- Perform many computations to refine and optimize device design
- Conduct a few highly diagnosed experiments to validate computational design

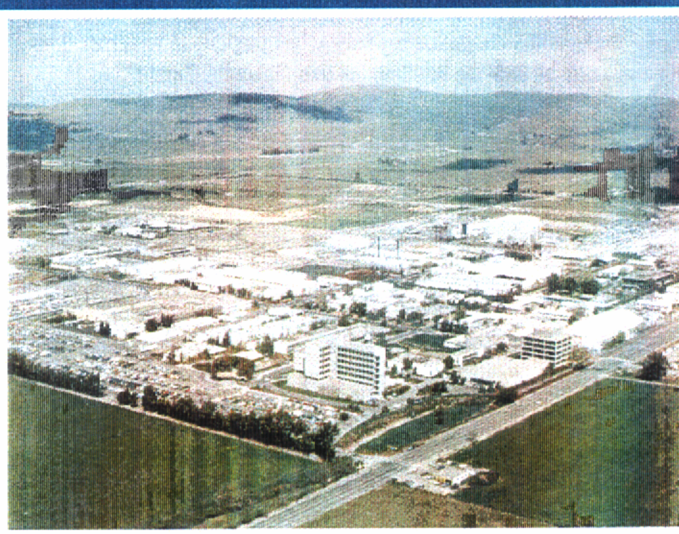
ASCI requires testing using highly diagnosed experiments

- Advanced Scientific Computing Initiative (ASCI) is intended to replace the role of full-up testing at the Nevada Test Site
- ASCI is developing super-fast machines using parallel architecture, parallelized hydrocodes, and improved material models
- However, the utility of ASCI-developed capability is highly dependent on experimental validation of both material models and the ability of the parallelized computations to accurately predict the results of integrated experiments

Role of dynamic testing at LLNL

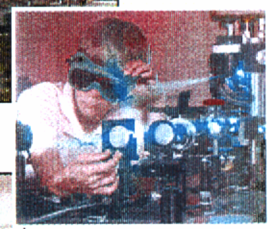
- To generate basic materials data
  - EOS, spall strength, cylinder tests, ...
- To perform basic science experiments
  - Metallic H_2
- To validate EOS and constitutive models
- To develop new capabilities and techniques
  - SHARP gun
- To validate hydrocode predictions of complex integrated experiments

The Lawrence Livermore National Laboratory is operated by the University of California for DOE

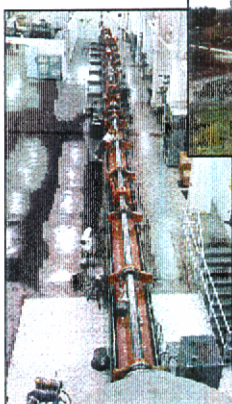


HEAF is a modern facility for explosives research and hydrodynamic experiments

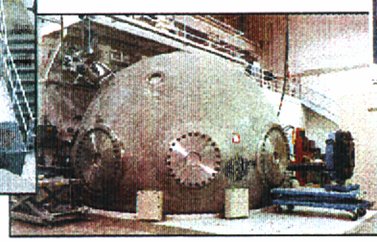
HEAF Facility



Microdetonics/DAC laboratory



4-inch gun

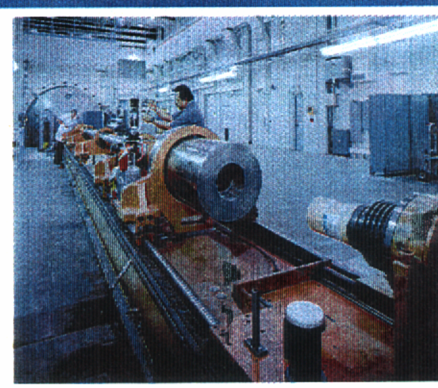


6 tanks (10-kg tank shown)

MOU-98-002. 10

Gas Gun (102 mm bore) in HEAF at LLNL

Diagnostics:
- At present:
  - Pressure
  - Shock velocity
  - Particle velocity
- In the future:
  - Optical:
    - Fibers
    - Streak camera
    - Framing camera
    - FP & visar interfer.



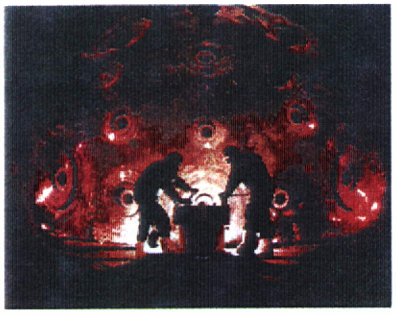
- The gun is capable of accelerating a 1 kg sabot to a velocity of 2.5 mm/μs
- Depending on the flyer material it can generate pressures in excess of 1 Mbar.

EMC ENERGETIC MATERIALS CENTER

MOU-98-002. 11

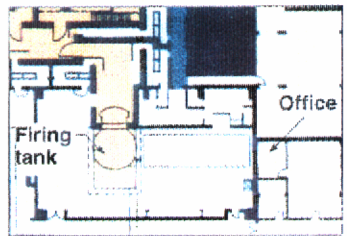
HEAF embodies safety and functional diversity

Damage-mitigated safety design



Can test up to 10 kg (22 lb) of explosives

People work close to each other and their experiments

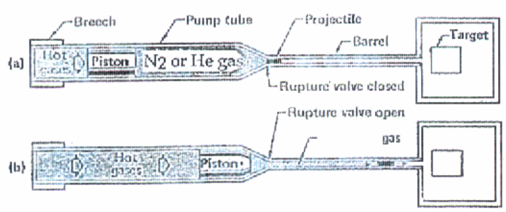


Chemists
Physicists
Engineers
Technicians
Support staff

ENERGETIC MATERIALS CENTER

Two-stage light-gas guns

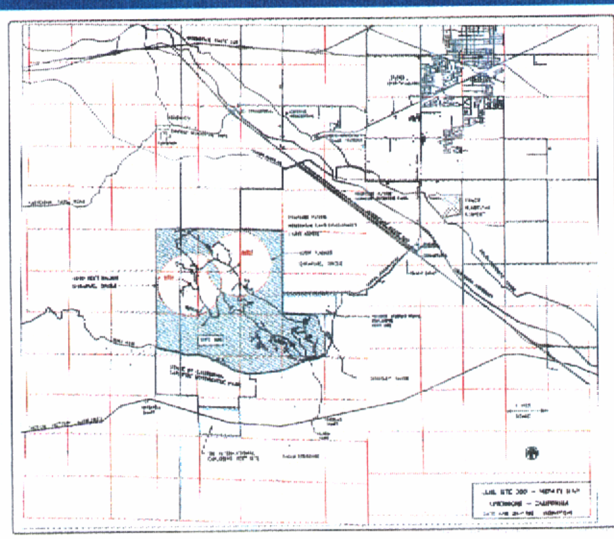
- Small gun:
  - Barrel length — 3 m
  - Barrel diameter: Velocity — 35 mm: 3 km/s; 20 mm: 4 km/s; 12 mm: 7 km/s
- Large gun
  - Barrel length — 9 m
  - Barrel diameter: velocity — 20 mm: 8 km/s; 28 mm: 8 km/s; 64 mm: 2.5 km/s
- Projectile velocity measurement — Flash x-rays
- Sample diagnostics — Electrical pins; VISAR; 6-channel optical; Electrical conductivity; Stock recovery



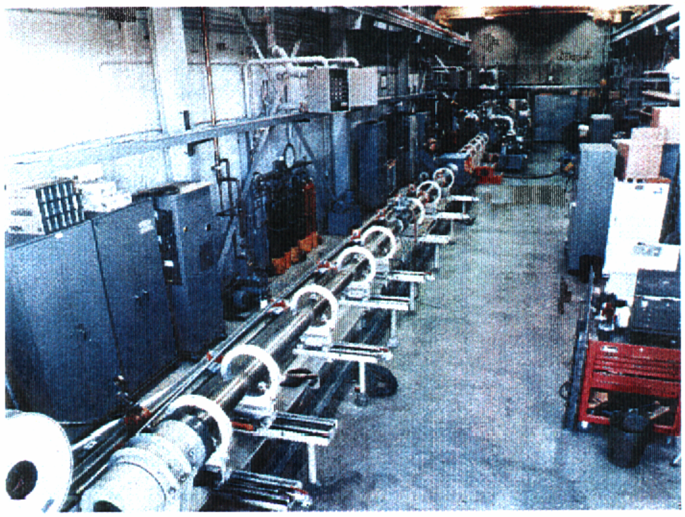
Testing facilities at S-300 and BEEF (NTS) are designed to integrate many or all of the available diagnostics

- Radiography (Linac, FXR, 6 each 450 keV)
- High resolution image converter camera (8 frames, 20 ns exposure)
- Multiple high speed framing and streaking cameras
- Multi-beam laser velocimetry
- Pin switches
- Other

Site 300 vicinity map

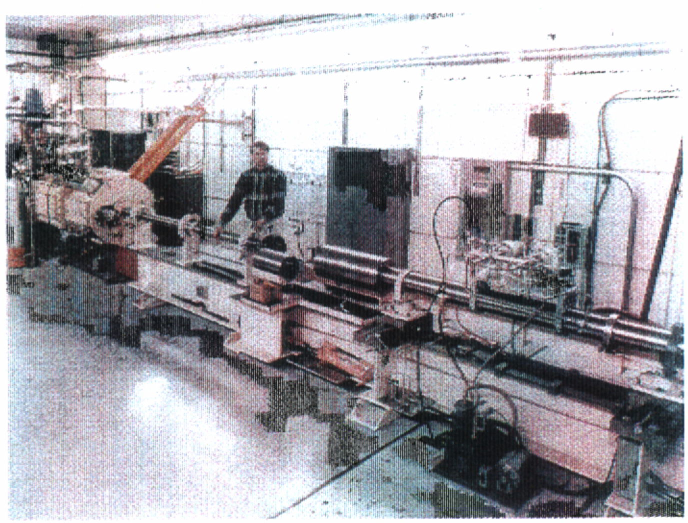


LLNL large two-stage light-gas gun



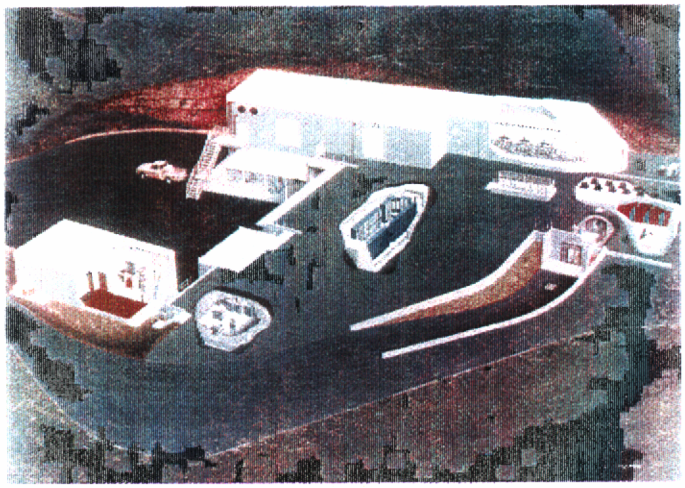
MOU-98-002. 14

LLNL small two-stage light-gas gun



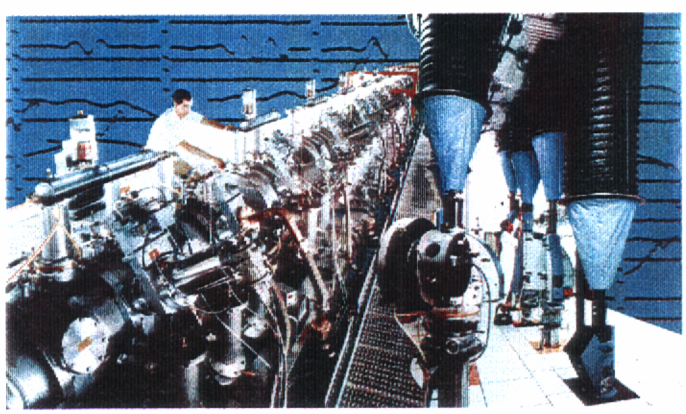
MOU-98-002. 15

Bunker 801 (FXR)



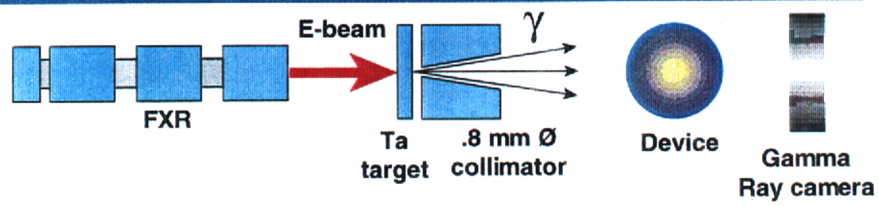
MOU-98-002. 18

FXR & Collage



MOU-98-002. 19

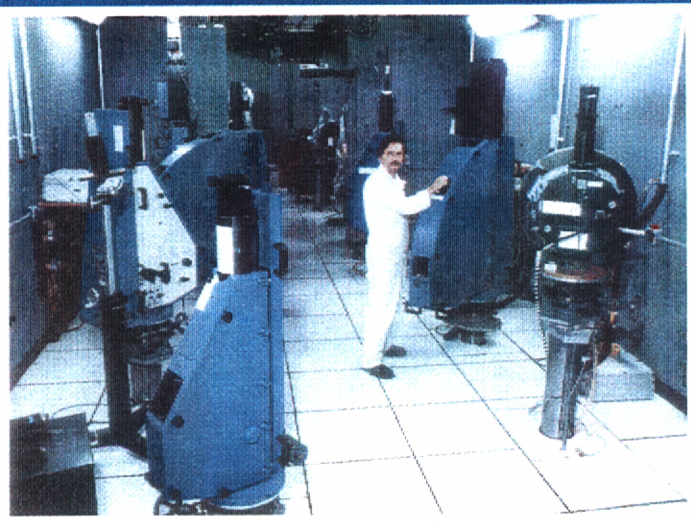
The FXR Upgrade Project goal was to enhance the radiographic capabilities of the B-Division Hydrotesting Facility



	Before	Goal (est. 1992)	Work in progress
Injector energy	1.2 MeV	2.5 MeV	2.25 – 2.5 MeV
Final beam energy	16 MeV	18 MeV	16 – 18 MeV
E-beam current	2.2 kA	3.0 kA	2.3 – 3.4 kA
X-ray dose (@1 m)	300 Rad	400 Rad	325 – 550 Rad
Spot size	2.2mm	1.6mm	1.9 mm
F.O.M. (for GRC)	69	156	127

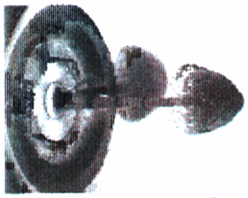
MOU-98-002. 20

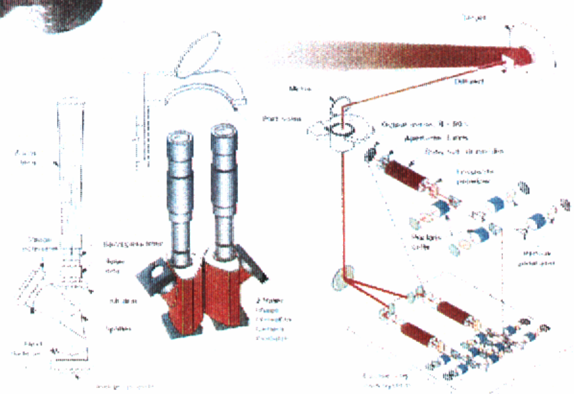
Camera room



MOU-98-002. 21

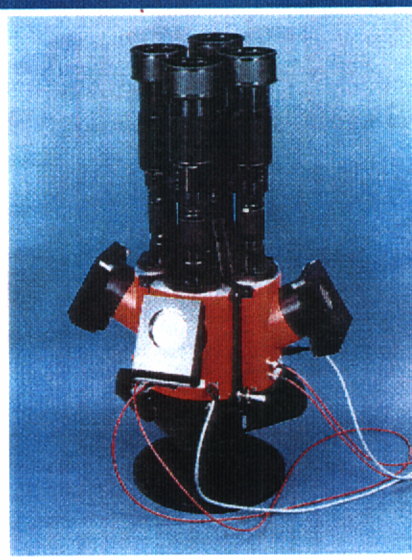
Laser-illuminated Image Converter (IC) camera





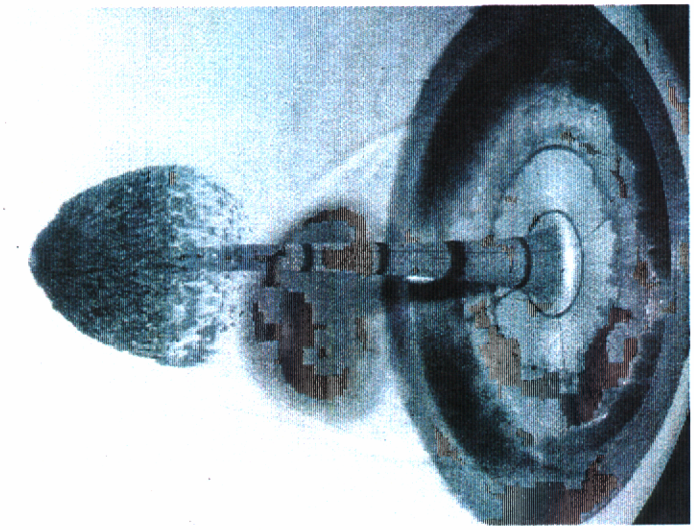
MOU-98-002. 22

Laser-illuminated Image Converter (IC) photo



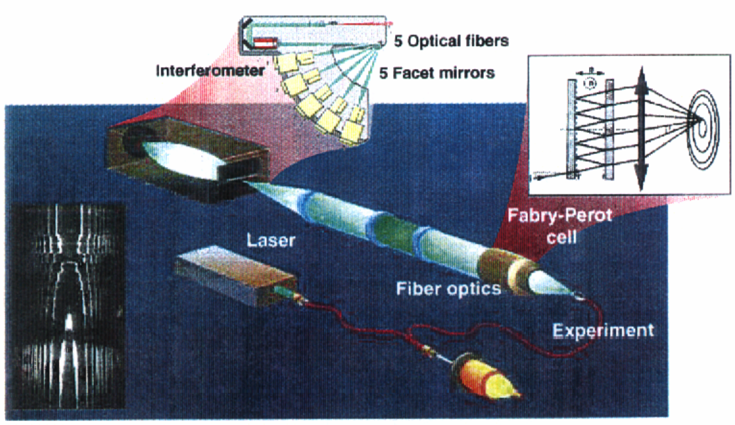
MOU-98-002. 23

IC camera image of viper shaped charge jet formation



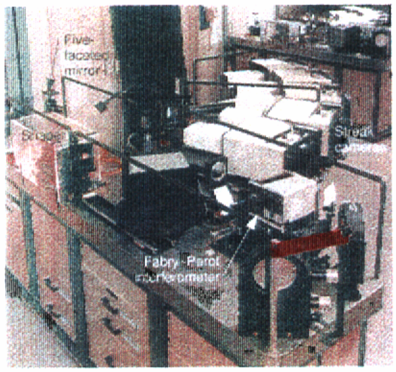
MOU-98-002. 24

Fabry-Perot velocimetry



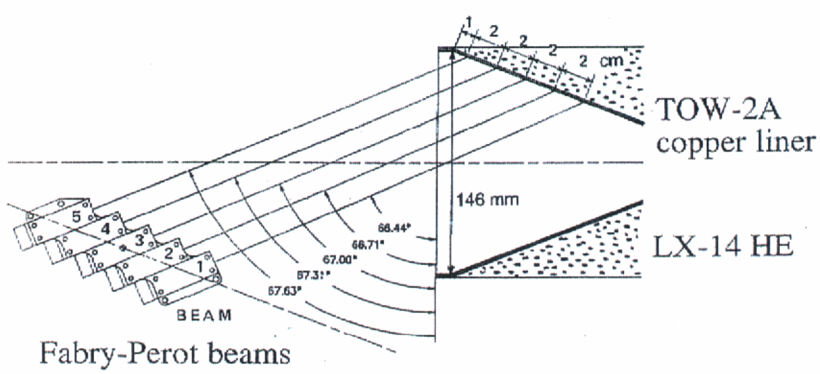
MOU-98-002. 25

By the end of the year, we will have completed three multibeam Fabry-Perot systems

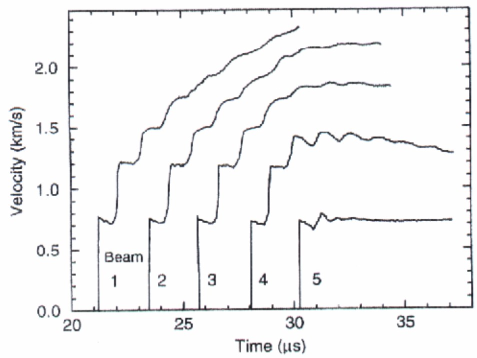


- A 5-beam system for laboratory Enhanced Surveillance measurements
- A 10-beam system for experiments at the NTS Big Explosive Experiment Facility (BEEF) and U1a Pu experiment
- A 20-beam system for hydrotest experiment

Experiment

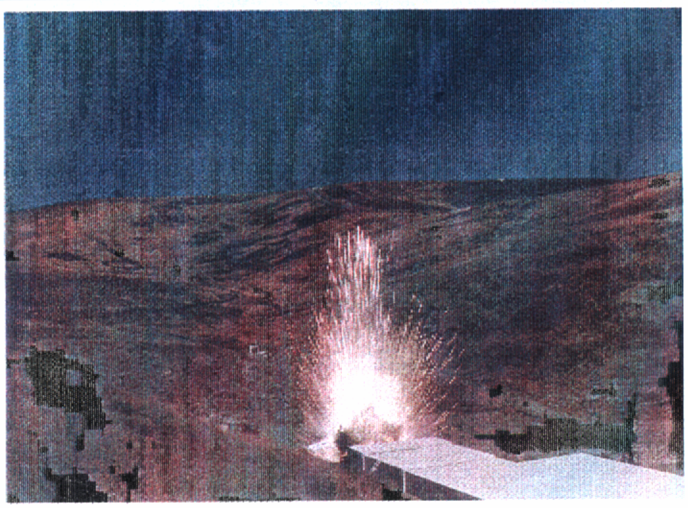


Measured Fabry-Perot velocity curves



- Early-time records are similar for all beams, and all show initial pull-back
- Late-time records show lower final velocities near base of liner, reflecting decreasing charge-to-mass ratios

975-C shot



The BEEF is at the Nevada Test Site

- 2500 kg within 5 m of camera bunker; >2500 kg beyond
- Three 2.3 MeV, wide-dispersion x-ray sources
- Five beam Fabry-Perot velocimetry (≈200 W/beam)
- Two or more Cordin 121 framing cameras; One Cordin 136 streak camera
- One image converter camera (4 frames with 20 ns exposure)
- Foil switches, ionization gauges, crystal pins, etc., with up to 100 digitizer channels

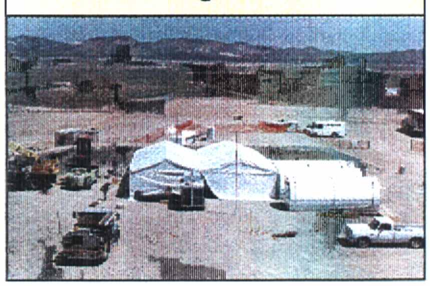
Area 4 NTS BEEF Big Explosives Experimental Facility

The Big Explosives Experimental Facility is a new LLNL hydrodynamic facility for large scale above ground evaluation of non-nuclear devices

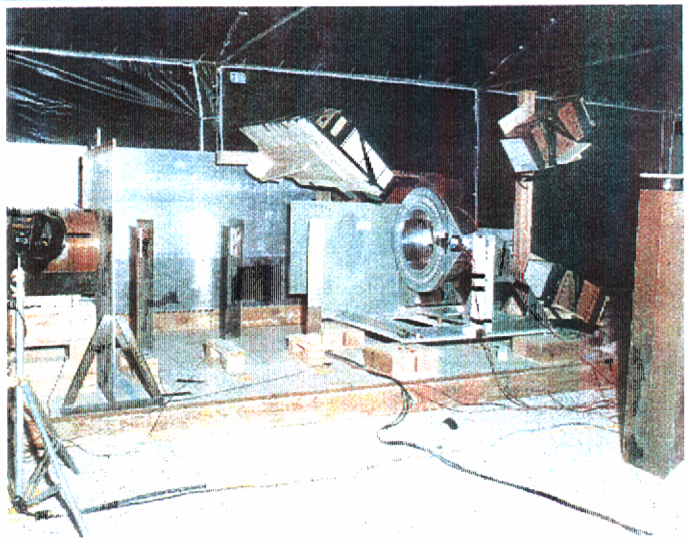
BEEF
Big Explosives Experiment Facility

- BEEF was activated for full manned operation March 1997
- NTS is an ideal location for a facility qualified for large-charge high-explosive experiments (70,000-lb TNT)
- Sophisticated diagnostics
- Approved DOE facility
- In use by both LLNL and LANL

Firing Table



Pre-shot photo of experiment setup



MOU-98-002. 32

Post shot

MOU-98-002. 33